ANALYSIS OF THE INDOOR PROPAGATION LOSSES FOR THE PORTABLE PHONE "POINTEL"

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ABSTRACT

The results of power loss measurements for the portable phone "Pointel" operating in the 864 - 868 MHz band are presented. These measurements were performed in the frequency domain using a network analyzer. Three indoor environments were considered for propagation experiments. Three methods for the power loss analysis are also described. From the obtained results, the radio coverage with both line-of-sight and obstruction of the direct path is derived.

I. INTRODUCTION

The measurements described in this paper were performed for the portable phone "Pointel", developed by SAT-Paris. This system operates in the 864 - 868 MHz frequency band and has 40 channels with 100 KHz bandwidth. For such a system, the well known global analysis [1], [2] is not sufficient. Indeed, the results given in this paper shows that the parameters of the relationship between the power loss and the distance between antennas are frequency-dependent in the considered frequency band. For this reason, the analysis was also carried out for each channel of the system. The obtained results are used to estimate for each channel the radio coverage. The comparison with the radio coverage estimated with the global method shows the utility of the analysis for each channel.

II. DESCRIPTION OF THE MEASUREMENTS

The measurement system [3] is built up around a HP 8753C network analyzer which generates a swept frequency signal from 864 MHz to 868 MHz in 801 equally spaced steps and analyses the received signal. The output of the network analyzer is connected to the transmitting (Tx) antenna through a 50 m coaxial cable with 8 dB attenuation. The calibration is performed at the output of this cable. The signal from the receiving (Rx) antenna is returned through a 4.5 m coaxial cable to the network analyzer to determine the S_{21} parameter. For each location of the Rx antenna, the magnitude of S_{21} was recorded.

Measurements were carried out in two different buildings: the principal building of INSA (The National Institut of Applied Sciences) and the railway station at Rennes. The environments considered in this paper consist of one corridor in the building of INSA and one corridor in the first floor of the railway station. For the first environment, the line-of-sight (LOS) was assured for each location of the Rx antenna (INSA-LOS). At the railway station, in the first situation, a similar scenario was chosen (R.ST.-LOS). For the second situation, the LOS was obstructed (R.ST.-OLOS).

The Tx antenna was elevated at 2.25 m. For each location of the Rx antenna, two values for its height were considered: 1.7 m and 1.2 m. During the measurements, both antennas were kept fixed. Concerning the time invariance of the channel, the measurements were performed during the night, in order to avoid the effects of the presence of people. The surrounding environment was kept stationary by preventing movements during the data acquisition.

In order to reduce the measurement noise, for each position of the Rx antenna, four measurements were performed (650 ms sweep time) and the results were averaged.

III. MEASUREMENT ANALYSIS

The main objective of these measurements is to determine the radio coverage, related to the power - distance relationship in the area.

III.1. Global analysis

For each frequency f_j ($1 \le j \le m$) chosen in considered frequency band and for each position of the Rx antenna, placed at a distance d_i ($1 \le i \le n$) from the Tx antenna, a value p_{ij} for the power loss was obtained. For each distance d_i, the m power loss values can be averaged. As usual [1], [2], [4], assuming that, for a given distance d, the average power loss can be expressed as:

$$\overline{P}(d) = A\, d^{\alpha} \qquad (1)$$

when the logarithm of (1) is taken, the following linear relationship accrues:

$$\overline{P}\,(dB) = A\,(dB) + \alpha\,[10 \log_{10}(d)] \qquad (2)$$

Using a linear regression analysis [5] between the average power loss and the distance, the minimum mean square error (MMSE) line is computed. All the results are given in Table 1.

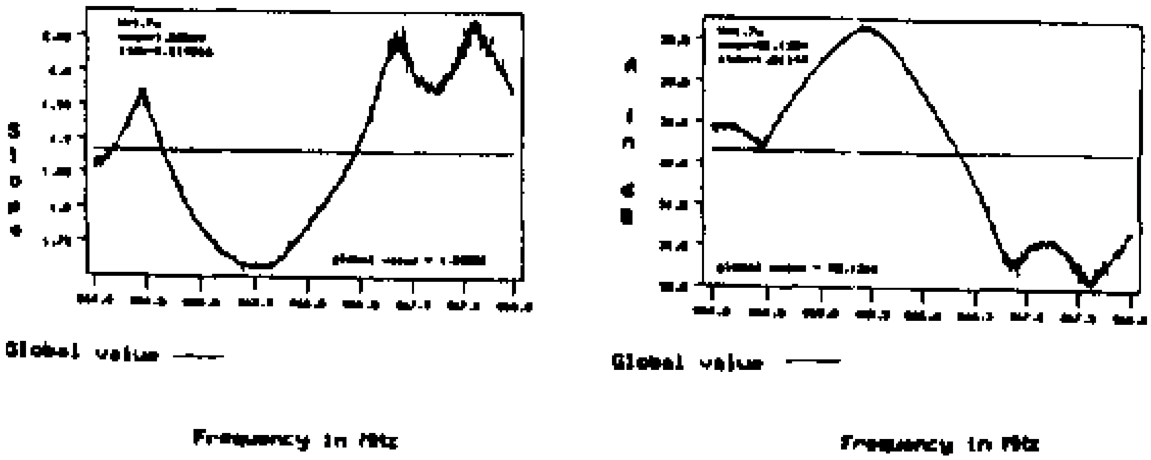
Table 1. *The results of the global analysis*

Environment	h [m]	α	A [dB]	error [dB]	correlation	n
INSA-LOS	1.7	1.539	36.30	2.79	0.912	40
	1.2	1.164	38.77	3.98	0.755	40
R.ST.-LOS	1.7	1.885	32.15	3.86	0.919	36
	1.2	1.168	37.90	4.89	0.742	36
R.ST.-OLOS	1.7	2.048	36.54	3.46	0.731	57
	1.2	1.844	41.06	4.21	0.620	57

We can see that $\alpha < 2$ for LOS environments. This indicates a wave guiding effect [6]. The corridor placed at the railway station (R.ST.-LOS) is larger than the other one (INSA-LOS); the top of the corridor presents an open zone and the ceiling is higher. For this environment, the propagation conditions resemble those associated with free-space. Thus, α is closer to 2. However, it can be observed that $\alpha < 2$ indicates a weak guiding effect. For the OLOS environment (R.ST.-OLOS), for h=1.7 m, the measurements indicate $\alpha > 2$. Thus, the propagation conditions are more difficult for the OLOS environments. As a general remark, α is greater for h=1.7 m. For h=1.2 m, the results obtained for LOS environments are almost the same. This indicates that for smaller values of h, the difference between the two environments is not very important.

III.2. Analysis for each frequency

The results given in Table 1 represent global values, useful to characterize in a general manner the wave propagation in the considered frequency band. However, it is possible to repeat this analysis for each frequency value. Thus, for each frequency f_j, the regression analysis between p_{ij} and d_i gives the values α_j and A_j. Fig.1. shows a plot of α and A versus frequency.



a) b)

Fig.1. a) *A plot of the slope versus frequency (R.ST.-LOS)*
b) *A plot of A parameter versus frequency (R.ST.-LOS)*

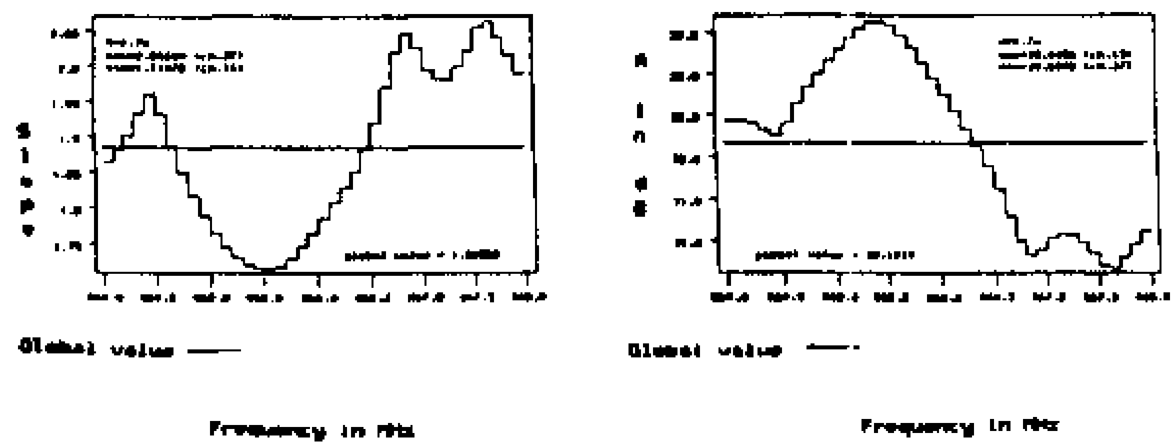
For each parameter, the global value obtained with the first analysis is also indicated. As in [4], some important conclusions can be pointed out:

1) the indoor radio channel presents a frequency selectivity; therefore, this analysis is useful for a better understanding of this transmission channel;

2) the averages of the 801 samples for α_j and A_j respectively are equal to the global values α and A obtained above. This is a general result that can be mathematically proved. The global values computed at the section III.1. can be deduced from the section III.2. by simple averaging over the frequency band.

III.3. Analysis for each channel

The "Pointel" system has 40 channels and every channel has 100 KHz bandwidth. Therefore, it is useful to analyse the relationship between power loss and distance for each channel of this system. It is possible to repeat the global analysis for each 100 KHz frequency band. However, there is an easier way to obtain the same results: it is sufficient to compute the average value of α or A for



a) b)

Fig.2. a) *A plot of the slope a for each channel*
b) *A plot of the A parameter for each channel*

each channel. In our case, for each channel there are 21 equidistant frequency values, so there are 21 values for α and A. The results are presented in fig.2. We can note the likeness with fig.1. These results can be used to compute the maximum distance between antennas for a given power loss value. The distances given in Table 2 were computed for 82 dB power loss. In each case, the analysis for each channel gives a smaller distance than the global analysis. These values assure the normal working for all the channels of the "Pointel" system.

Table 2 *The maximum distances between antennas*

Environment	h [m]	d_{max} (global value)	min{ d_{max} }
INSA-LOS	1.7	928 m	807 m
	1.2	5.15 Km	3.7 Km
R.ST.-LOS	1.7	440 m	309.5 m
	1.2	5.95 Km	918 m
R.ST.-OLOS	1.7	165.6 m	127.4 m
	1.2	165.6 m	118.5 m

CONCLUSIONS

Power loss measurements of the indoor radio channels have been performed in the 864 - 868 MHz band. Three environments were chosen and each time, two values for the height of the receiving antenna were considered. Three post processing methods were described. The obtained results were used to evaluate the radio coverage.

The distances obtained with the results of the analysis for each channel are more reliable and accurate than those obtained with the global analysis.

The analysis described in this paper can be used for other wireless systems with several adjacent channels.

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REFERENCES

[1] Howard, S.J. and Pahlavan, K.: "Measurement and analysis of the indoor radio channel in the frequency domain", IEEE Trans., IM-39, 1990, pp.751-755

[2] Smulders, P.F.M.,Wagemans, A.G.: "Wideband indoor radio propagation measurements at 58 GHz", Electron.Lett., Vol.28, No.13, 1992, pp. 1270-1272

[3] Zaharia, G., El Zein, G. and Citerne, J.: "Time delay measurements in the frequency domain for indoor propagation", IEEE AP-S Dig., 1992, pp.1388-1391

[4] Zaharia, G., El Zein, G. and Citerne, J.: "Wideband measurements and analysis of propagation losses within a building", IEEE AP-S Dig., 1992, pp.1380-1384

[5] Urkowitz, H.: "Signal theory and random processes", Artech House Inc., Washington, 1983, Ch.7

[6] Lafortune, J.F. and Lecours, M.: "Measurement and modeling of propagation losses in a building at 900 MHz", IEEE Trans., VT-39, 1990, pp.101-108